NEW CAPABILITIES OF

WALSH FUNCTIONS AND WALSH TRANSFORMS

Interim Scientific Report

(Covering period from 1 April 1976 to 31 May 1977)

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by

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I. Introduction

The overall objective of this research is the exploitation of the capabilities of walsh functions and Walsh transforms with special reference to the development of efficient computational algorithms and the solution of nonlinear differential equations. The binary character of Walsh functions and Walsh transformation matrices is advantageous for applications with digital computers and will, in many cases, reduce the time required for processing signals. Work in the period covered by this report proceeded in several directions: solution of difference equations; development of an algorithm for sequency ordering of Hadamard functions; development of a generalized orthogonal transformation matrix; and analysis of nonlinear systems.

II. Research Progress

1. Solution of Difference Equations: Several time-shift theorems for Walsh transforms of functions subject to nondyadic as well as dyadic time displacements have been formulated. Spectrum-conversion matrices have been defined and a relation between a function with an ordinary shift and that with a dyadic shift has been established. It has been demonstrated that the use of Walsh transformation facilitates the determination of the recursive formulas of systems governed by difference equations.

2. Sequency Ordering of Hadamard Functions: The order of a Hadamard function, unlike that of a Walsh function, is, in general, not equal to its

sequency. A simple algorithm has been developed for obtaining the sequency vector of high-order Hadamard transform matrices without the need for converting the order of individual Hadamard functions to sequency.

3. Generalized Orthogonal Transformation Matrix: A procedure has been developed for generating a two-parameter orthogonal transformation matrix which reduces to the Fourier and Hadamard transformation matrices under special conditions. The generalized transformation matrix is particularly useful for multidimensional signal processing on a real-time basis because it preserves a proper relationship in the transform domain.

4. Analysis of Nonlinear Systems: An alternative method for obtaining the steady-state solution of a nonlinear differential equation has been found by starting with a finite polynomial representation of a time-continuous function and defining a Walsh polynomial-conversion matrix. The relations between the coefficient vectors of the derivatives and the integrals of the polynomial can be derived and used to solve nonlinear differential equations.

III. Publications

1. D. K. Cheng and J. J. Liu, "Time-shift theorems for Walsh transforms and solution of difference equations," IEEE Transactions on Electromagnetic Compatibility, Vol. EMC-18, May 1976.

2. D. K. Cheng and J. J. Liu, "An algorithm for sequency ordering of Hadamard functions," IEEE Transactions on Computers, Vol. C-26, March 1977.

3. D. K. Cheng and J. J. Liu, "A generalized orthogonal transformation matrix," a scientific report to be published in June 1977.

IV. Future Plans

In the next period attention will be directed, but not limited, to the following tasks:

1. To solve typical nonlinear differential equations by the proposed alternative method and to investigate the convergence and error-propagation properties of the iterative Walsh-function procedure.

2. To study methods for solving homogeneous difference equations with nonquiescent initial conditions.

3. To examine the use of Walsh functions and Walsh transforms for solving nonlinear difference equations.

4. To develop a fast algorithm for computing dyadic convolution.

5. To investigate the application of Walsh-transform methods for the analysis of the channel noise in a pulse-code-modulation system.

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Research progress has been in four areas: (1) Solution of difference equations; (2) Sequency ordering of Hadamard functions; (3) Generalized Orthogonal transformation Matrix; and (4) Analysis of Nonlinear Systems.

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